Reactor-Boiler and Auxiliaries - Course 433

# NUCLEAR POWER

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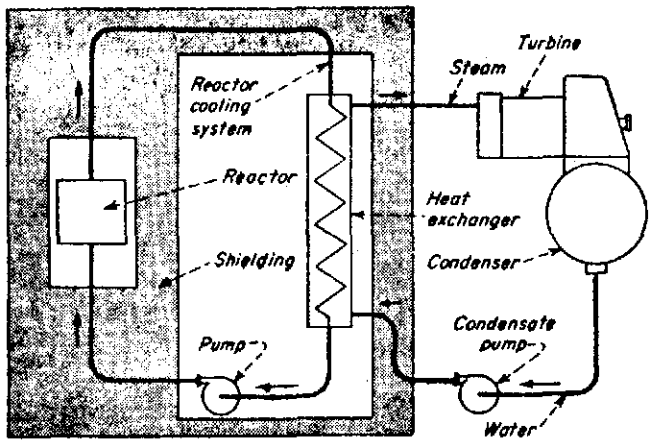
Nuclear power is being developed, not just as a cheap source of energy for the present, but also because available reserves of coal, oil and gas are definitely limited. An estimate of the future energy use and total amounts of fossil fuel which can be recovered at up to twice the present cost, indicates that the reserves will run out in about 100 years. There is, however, a potential of nearly 20 times this amount of energy in the world's resources of uranium from economically acceptable uranium ores.

Since there is a close tie between the energy consumption and standard of living in any country, there is a strong incentive to develop sources of energy as required to prevent a future energy shortage.

The lessons on Reactor-Boiler and Auxiliaries will describe the equipment and systems necessary to make use of uranium as a fuel and convert it into useful heat energy for steam generation.

## Nuclear Power Stations

In a nuclear power station, the reactor can be compared to the furnace in a conventional station, not because they look the same, but because they both do the same job, supply heat. This heat can then be transferred in a heat exchanger to generate steam that can spin the rotor of a turbine-generator. The turbine-generator, condenser and pumps in the steam cycle are very similar to the equipment in a conventional station. Figure 1 shows a simplified circuit of a nuclear power plant.




A simple nuclear power plant has a reactor delivering heat to an exchanger to generate steam for a conventional turbine unit.

Fig. 1

## Heat Generation from Fission

As noted previously, the purpose of the reactor in a nuclear power station is to supply heat. This heat results from fission and thus a basic understanding of fission and the chain reaction is fundamental to a study of nuclear reactors.

As studied previously, an atom consists of a nucleus made of neutrons and protons surrounded by electrons in various orbits. A free neutron has no charge and can penetrate into the nucleus of an atom without being affected by the negatively charged electrons or positively charged protons. If a neutron enters a mass of uranium and strikes the nucleus of a Uranium-235 atom, there is a certain probability that the nucleus will split (fission). This splitting or fissioning will release the enormous

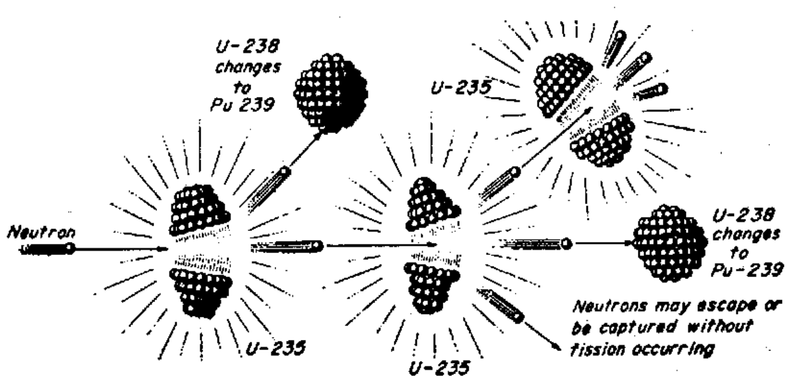



Fig. 2

amount of energy that binds the nucleus together to generate heat in the mass of uranium. In addition, the fissioned nucleus ejects two or three neutrons at high speed. These, in turn, charge through the uranium mass to heat and fission other nuclei. (Fig. 2)

This chain reaction can proceed (1) at explosive speed with the number of ejected neutrons multiplying infinitely, as in an atom bomb, or (2) at a controlled rate with the released neutrons building up to a certain level and remaining there, as in a reactor. An atom bomb, however, uses very concentrated U-235 (Uranium-235) extracted at great cost from natural uranium. A Canadian power reactor uses natural uranium, which contains only 0.7% of U-235.

With U-235 being the only natural fissionable material, it would appear that only 0.7% of natural uranium can be used. The U-238, however, has an important characteristic. If it absorbs a stray neutron, it changes after a delay of several days, into a new element, plutonium-239, which fissions just like U-235. Thus plutonium, not found in nature, is a man-made fissionable material. Also, U-238 can fission with neutrons of high energy level and contribute to the chain fission process to produce heat energy. This means that we can more nearly utilize all of the natural uranium as an energy source, not just 0.7%. We call U-238 a "fertile" material; - one that can be converted to a fissionable material.

Figure 2 shows U-235 atoms splitting into two new chemical elements (fission products) with the release of neutrons and heat energy. Therefore, in a nuclear reactor, the fuel is being constantly depleted and replaced by these "waste products" (fission products). These can act as a "poison" to the reactor, by wastefully absorbing neutrons and interfering with the chain reactions. One of the important fission products is Xenon-135 which absorbs a large number of neutrons.

## Basic Reactor Components

Some of the terms used to describe major reactor components in these lessons are:

Fissionable Material and Fuel: Fissionable material is material whose atoms will split or fission when struck by a neutron and, as a result, release energy. The important fissionable materials in Canadian Reactors are Uranium-235 and Plutonium-239. Reactor fuel is an assembly or group of assemblies which have fissionable material contained in a metallic sheath.

Moderator: is the material which is used in the reactor to slow down neutrons so they will be effective in causing more fissions.

Heat Transport System: is the system which carries heat energy from the reactor fuel to the steam generator.

Reflector: is the material which surrounds the fuel and moderator and helps prevent escape of neutrons by bouncing them back into the core where they may cause fissions.

Shielding: is the material surrounding the reactor or any radioactive systems to reduce the escape of radiation to an acceptable working level for personnel.

Reactor Core: normally the material in the reactor vessel. This includes the fuel, moderator, and part of the heat transport system which is in the reactor vessel.

## ASSIGNMENT

1. What is the main purpose of a reactor in a nuclear power station?

2. Why is it important that additional neutrons are released when an atom fissions?

3. What is the purpose of:

    (a) the moderator?

    (b) the heat transport system?

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